DEVELOPMENT OF SMART DISINFECTION MACHINE USING IOT TECHNOLOGY

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In this study, the authors developed a smart, high power of disinfection machine using IoT technology. This disinfection machine generates super fine fog from H2O2 solution by utilizing pressure-swirl airblast atomizer. This machine sprays the H2O2 fog into the air inside the operating room in hospitals to disinfect and make the environment clean. The operation of the disinfection machine is totally remote controlled via mobile application using Bluetooh Low Energy (BLE) communication technology. All operating parameters are remotely, real time monitored and controlled. In addition, the machine operation history of are fully collected and stored both on a memory card in control circuit board and on cloud database. Furthermore, the heat generation from the integrated circuits (ICs) or chip and electronic components on the control printed circuit board (PCB) is also studied in order to prevent the overheating of the components which cause malfunction or instability of the machine. The results show that the temperature of all the electronic components on the control PCB during working is within the temperature allowance, and the disinfection machine works well.

KEYWORDS

Internet of Things, disinfection machine, smart machine

1 INTRODUCTION

Recently, together with the development of internet and wireless communication technologies, the development of internet of things (IoT) is blooming in many fields such as home appliances, healthcare services, industrial sectors, and agricultural sectors, etc. IoT is considered as a revolution for the next technology era which is changing human lives in a way never imagined before. An IoT system is dynamic and self-configuring network of physical and virtual objects which are powered with interoperable communication protocols, media and standards [1-3]. In IoT world, smart objects are connected with each other which enables real-time interaction between machine-to-machine, human-to-human and machine-to-human even at a long distance. IoT brings a lot of advantages such as providing real-time resource visibility, real-time controllability and automation of the connected devices, reduced costs and improved operational efficiency, etc. Therefore, a lot of efforts have been put in research and development of IoT systems applying in smart home [4-7], educational applications [8-10], healthcare and medical services [11-13], industrial manufacturing systems [14, 15] and agricultural fields [16,17], etc.

Smart home together with IoT means that any appliances in houses are possibly communicated and interacted with the user through the internet, and the information of all the connected decives in the house can display on screens of smart devices. Hence, smart homes make human life easier and more convenient by saving effort, time, and resources. Recently, a lot of attractions from researchers have been put in research and development of smart home systems and applications. Smart homes systems based on PLC control were reported [5,18-20] in order to control the operation of the in door electrical devices such as light bulb, air conditioner, fan, switches, power socket, etc. Furthermore, smart homes systems were developed by using different controller and kit such as Adruino [6,21,22], and ESP32 microcontrollers [7,23,24].

In addition, IoT systems are also developed for remote laboratories in education sectors [8-10] which enables students to conduct experiments remotely. These kind of distance laboratories are very usedful and highly desired in case of sharing complex and expensive facilities or in case of serious pandemic such as Covid-19.

Moreover, IoT is intensively developed and applied in the healthcare field [11-13]. Up to date, IoT in healthcare is considered one of the most popular technological trends all over the world. A lot of IoT systems and applications have been developed and applied in healthcare in order to improve the its efficiency, accessibilty, convenience, and reduce operation costs [11-13]. Joseph S. et al. [25] developed an IoT intravenous drip monitoring system including both hardware and software which collecting real time health data from patient and automate droplet monitoring systems. Moreover, heart rate, blood pressure, temperature, and fluid level were monitored in real time via Bluetooth media, and alert messages would be sent to nurses or medical staffs if one of these values were out of threshold. The result of this research was helpful to reduce adverse effects of intravenous drip injection in hospitals. However, the operation stability of this system was not mentioned. Especially, when the number of in-used devices is large, the data transformation is large, the heat generated from the controller and PCB would cause malfunction of the system. Nursuwars F.M.S. et al. [26] reported an Development of an RFID-based nurse call IoT system which allows patients to remotely call nurses or other healthcare staff for the support. Against, this system was only prototyping demonstration about the conceptual function. The heat generated from the controller and PCB was not mentioned. This issue is very important to the operation stability of the system. Narendra K. S et al. [27] developed a real-time health monitoring system which includes hardware (i.e. Raspberry Pi 3, GSM and Wi Fi module, blood pressure, heart rate and temperature sensors) and applications on both computer and smart phone. The system can collect basic health parameters of patients and store in the database by means multiple modes of communication. Therefore, the risk of lossing track of data of a patient is minimized. However, the heat generated from the controller and PCB of the prototyping system was not considered. Some other IoT systems for fall detection of elder people were also reported [29-30]. These system is a warable device which normally includes controller, integreated accelerator sensors and gyroscopes, and wireless communcation modules. Base on the suddenly changes in accelerates collected from wearable device on people, the fall is detected. Heat arising from the electronic components on the wearable device is a cririical issue which affects not only the performance of the devices, but also affect the comfortness of the people using the device. Nevertheses, the heat generation from the developed devices were not studied and presented.

In this study, the authors developed a smart disinfection machine which the machine operation can be controlled and monitored via an application in a smart phone. The machine is able to generate super fine fog from H2O2 solution by using a pressure-swirl airblast atomizer. The machine operating parameters such as working time, disinfection location, air blow motor temperature, H2O2 solution level, output disinfection solution concentration, etc. are real-time monitored and controlled. The machine can be operated with several pre-setting modes (quick start modes) or advanced mode (customizable mode). In addition, the operation history of the machine are fully collected and stored both on a memory card on controll PCB and on cloud database. It is possible to retrieve pre-setting operation parameters which were used in previous sessions for a specific room by using registered quick response code (QR code) for the room. By tracking the operation history of the machine, suitable maintenance activities can be conducted. Therefore, it improves the efficiency and life time of the machine. Since, heat arising from integrated circuits (ICs) or chip, electronic components on the control printed circuit board (PCB) plays key roles on the stable performance and life time of the machine. Therefore, it is necessary to study the heat generation from the electronic components on the control PCB in order to ensure all the electronic components are operated under the normal conditions. In this study, the heat generation from electronic components on the control PCB is studied by both simulation and practical experiments.

2 DESIGN AND MANUFACTURE OF SMART DISINFECTION MACHINE

In this research, the authors developed a smart, high power of disinfection machine which the generates super fine fog from H2O2 solution by utilizing pressure-swirl airblast atomizer. Figure 1 shows the design, arrangement of components, and the manufactured disinfection machine developed in this study.

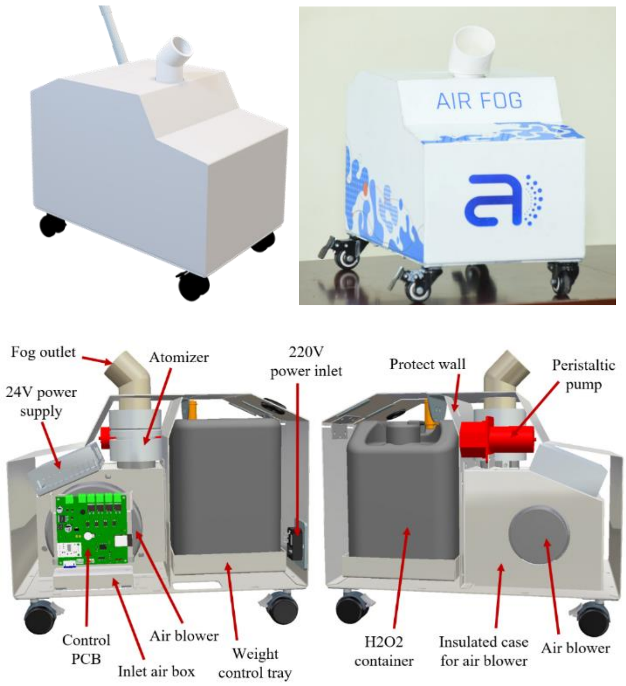


Figure 1. 3D model design and manufactured disinfection machine

The working principle of the disinfection machine is described in the Figure 2. The H2O2 solution of 5% concentration is supplied into a pressure-swirl airblast atomizer by using a peristaltic pump. In addition, air is blown into the pressure-swirl airblast atomizer by using an air blow motor (Lamb Ametek 119625). The air flow rate is 50 l/s, and the flow rate of H2O2 solution is controllef from 30 ~ 40 ml/min. Under the pressure-swirl airblast inside the atomizer, the H2O2 solution is seperated and splited into fine fog at the outlet of the atomizer. The fine H2O2 fog is blown and diffused into the room space which would be disinfected.

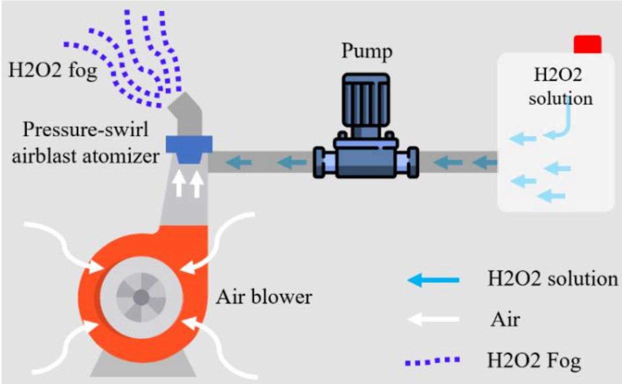
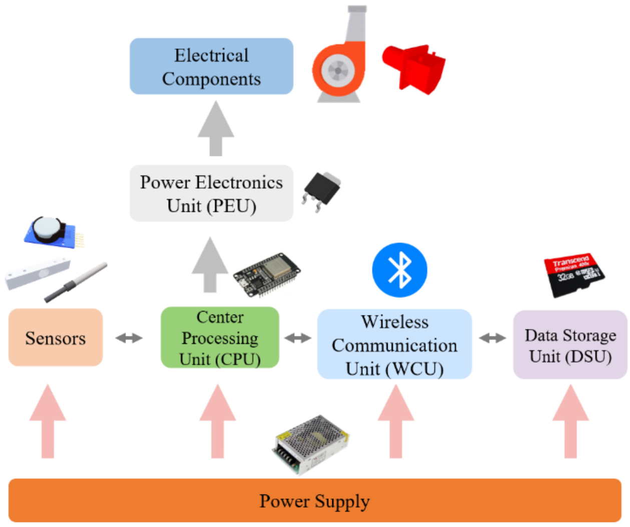


Figure 2. Working principle diagram of the disinfection machine

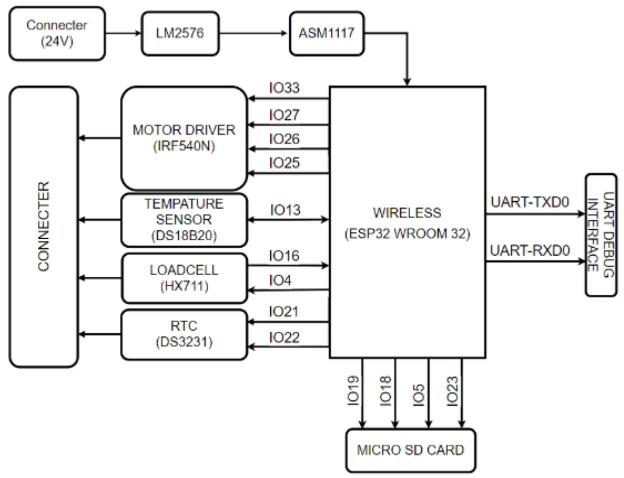
Figure 3 (a). shows the block diagram of the control system of the disinfection machine. The system consists of the following units:

- Center processing unit (CPU): This is the main control unit of the machine. The CPU receives the operation control commands from the wireless communication unit (WCU) via the Bluetooth protocol. Furthermore, CPU also assures the proper operation of the disinfection machine and avoids the problems such as over heat, run out of disinfection solution. This is because the CPU continuously collects the data from thermocouple and loadcell, and controls the working condition of the machine in a predefined proper range.
- The sensor unit consists of thermocouple, loadcell, and a programmable real time units. The thermocouple measures the temperature of the air blow motor which is the main power consumption component of the disinfection machine. The loadcell dynamically measures level of H2O2 solution remaining inside the container. This sensor unit measures the working condition of the machine such as the temperature, the disinfection solution level, etc. and sends the data to the CPU.
- Power electronic unit (PEU): The role of this unit is to amplify the control signal from CPU to the electrical components such as turning on/off the air blow, adjusting the flow rate of the peristaltic pump, etc.
- Wireless Communication Unit (WCU): this module helps the CPU to communicate with remote control device such as a smart phone via Bluetooh Low Energy (BLE). All the working parameters of the disinfection machine are controlled, monitored, and collected via this application, and then sends this data to the database on cloud.
- The data storage unit (DSU): stores the working data of disinfection machine into a flash memory card integrated on the PCB for further processing and analyzing working data of the machine. The working data of the machine is temporatorily stored on the flash memory card for some period of time. As soon as the the data is synchronized on cloud database, the memory of the card can be released.
- The power supply: supplies proper electrical power for the whole system.

Figure 3 (b). shows the connection diagram of the components of the control system with the connection indentification numbber (ID number, ie. The input – output ID).



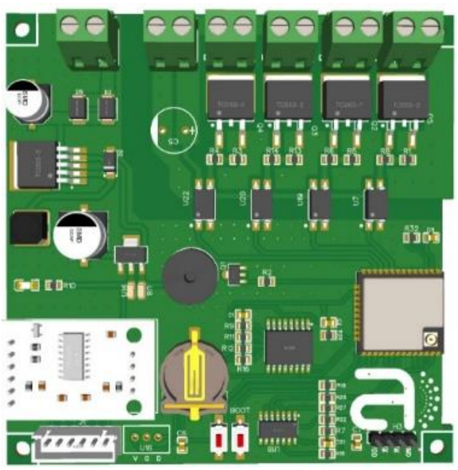
(a). The block diagram of the control system of the disinfection machine



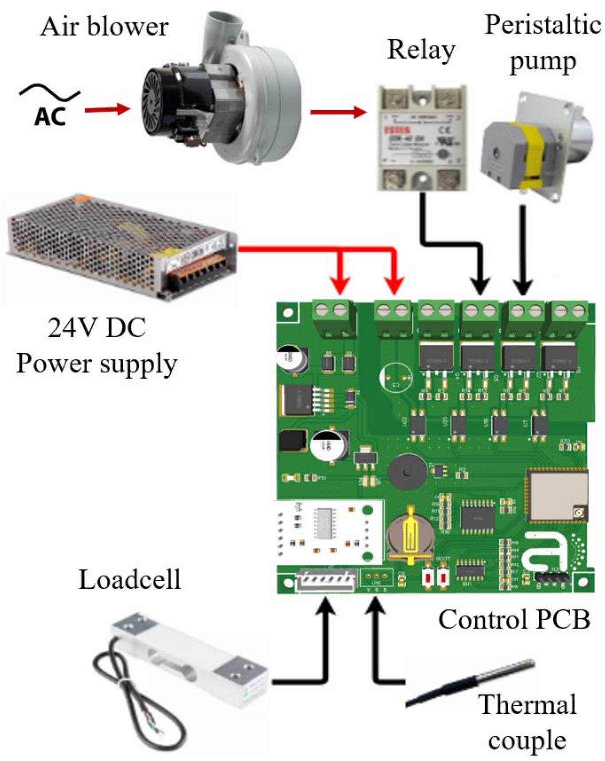
(b). Connection diagram of components of the control system of the disinfection machine.

Figure 3. Block diagram and connection diagram of the components of the disinfection machine

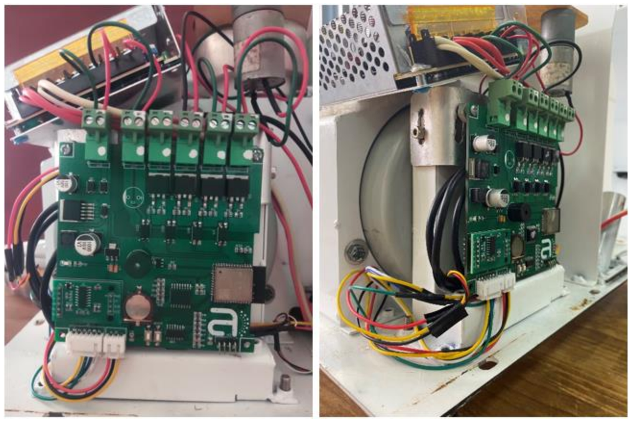
Figure 4 (a). shows the design of the control PCB of the disinfection machine. The control PCB is designed using Altium designer software. Figure 4 (b). shows the connection diagram between the components of the disinfection machine and the control PCB. Figure 4 (c). shows the manufactured control PCB after completing wiring with the components of the disinfection machine.



(a). Design of control PCB of the disinfection machine



(b). Connection diagram of components with the control PCB of the disinfection machine



(c). Manufactured of control PCB of the disinfection machine

Figure 4. Control PCB and connection of components of the disinfection machine

3 DEVELOPMENT OF MOBILE APPLICATION FOR CONTROL DISINFECTION MACHINE

In this study, the control application is developed by using Flutter inside Android Studio. Flutter is an open-source Software Development Kit (SDK) which provides tools to quickly design the user interface for both smart phone, website, and personal computer. The database of the control mobile application is stored on the cloud by using Firebase which is a set of backend cloud computing services and application development platforms provided by Google. The application is built for smart devices running in Android operation system.

Figure 5 shows some main tabs of the user interfaces of the application for Android smart phone. Figure 5(a) shows the login interface where an user uses a registered account (i.e. Email address and password) to login the application to operate the disinfection machine. Figure 5(b) shows the quick run interface where an user can run the machine quickly with default settings from manufacturer; the user can set the working time conveniently for the spray session. Figure 5(c) shows the check component interface where an user can test working properly status of each component such as air blower motor, peristaltic pump, alarm, etc. independently or simultaneously. Figure 5(d) shows the machine setting interface where an user can do all the setting for the machine such as setting bluetooth connection, setting disinfection condition parameters, etc. Figure 5(e) shows the machine working history interface where an user and the manufaturer can track the working history for every run session. The working history is then used for evaluate the quality of the machine, and also used for maintenance planing.

Figure 5(f) shows the maintenance history interface where an user and the manufaturer can track total working time of the machine, the number of errors occurs and maintenance history of the machine. A warning for maintenance activity is also recommended for users based on total working time of the machine.

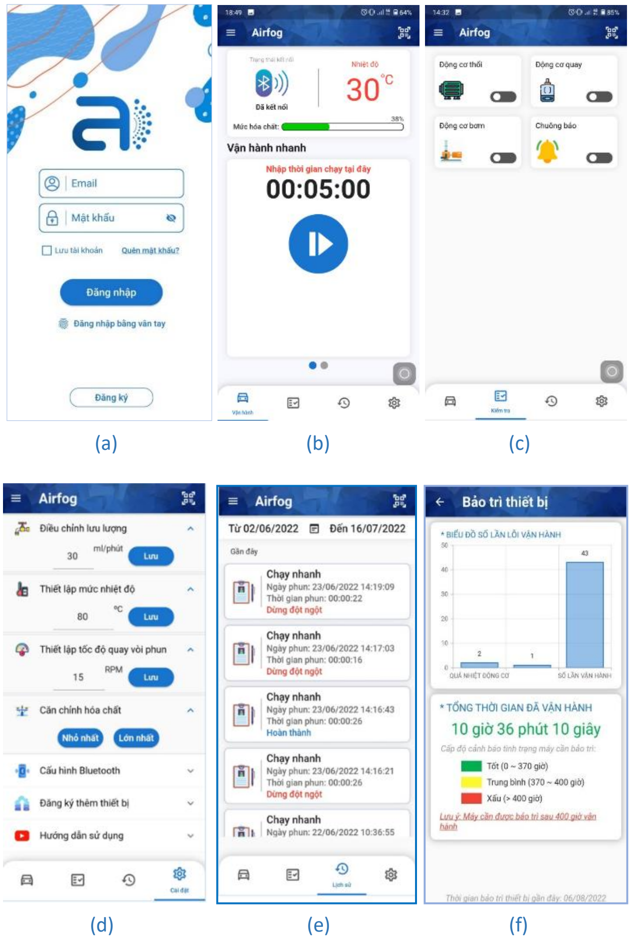


Figure 5. User interfaces of the application in Android smart phone; (a) Application login interface; (b) Quick run interface; (c) Test main components interface; (d) Setting disinfection parameters interface; (g) Machine run history interface; (f) Machine maintenance history interface

4 STUDY HEAT DISTRIBUTION OF THE CONTROL PCB

The heat generated from the control PCB plays key role on the stability opertation of the disinfection machine and the lifetime of the electronic components. It was reported that more than 50% of all integrated circuit (IC) failures caused by the failure of thermal management [31, 32]. In addition, it is also reported that a 10°C increment in operating temperature of the electronic devices can cause a 50% reduction of lifetime of the devices [33, 34]. Therefore, it is necessary to study and evaluate the heat generated from the control PCB of the disinfection machine. In this work, the heat distribution on the components and the PCB is studied by using both numerical simulation tool and practical measurements to validate the heat generation results. The heat simulation is conducted using the Hyperwork CFD software. Then practical measurement of the temperature of the components conducted by using thermistors attached directed on the components.

4.1 Nummerical simulation of heat distribution of the control PCB

Figure 6 shows the model used for studying heat distribution on the control PCB. Three main heat sources generated in the disinfection machine are: (1) heat generated from the air blow motor; (2) heat generated from the power supply; and (3) heat generated from the electronic components on the control PCB.

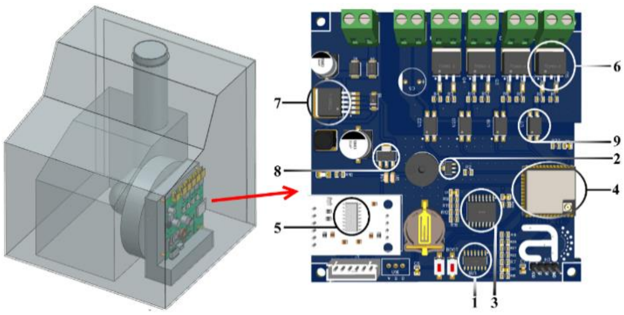


Figure 6. Model for studying heat distribution of the control PCB of the disinfection machine

In order to calculate the heat generated on the electronic components on the PCB, firstly, the heat generated from the air blow motor and from the power supply is studied. Then, it is assumed that these two heat sources are stably affect on the heat distribution of the control PCB by the convection effect. The heat transfer by radiation is too small so that it is negligible. The heat genetated on the control PCB is come from not only operating electronic components on the PCB, but also from the heat transfer from the air blow motor and from the power supply by convection effect.

Figure 7 shows the simulation results of heat distribution of the electronic components on the control PCB. It is observed that the temperature of the components is varied from 308.9 K to 315.2 K (or 35.7 ºC ÷ 42.2 ºC). The simulation temperature and the working temperature range of each electronic components are show in the Table 1.

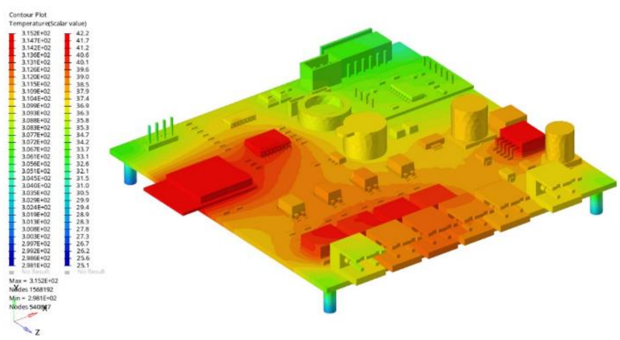


Figure 7. Heat distribution of the insulating case of the air blow

It is found that the maximum temperature of the all components is about 315.2 K (or 42.2 ºC) which is in the normal working temperature range of all components. Therefore, from the heat generation point of view, all the electronic components work well.

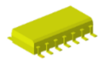
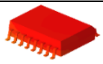
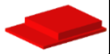
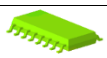
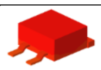
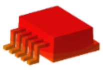
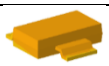
No	Photo of components	Name of components	Watts per unit volume (W/m3)	Simulation Temperature (°C)	Normal Working Temperature (°C)
1		74LVC125 AD	877192.9	37.5	-65÷150
2		D882	2058823.5	37.4	-55~150
3		DS3231	2116402.1	41.7	-40~85
4		ESP32	760456.3	42.2	-40~105
5		HX711	126948.1	35.7	-40~85
6		IRF540N	426439.2	41.2	-55~175
7		LM2576	1173708.9	41.7	-40~125
8		NCP1117	2414634.1	38.5	-40~125
9		PC817XI	185185.2	39.0	-30~100

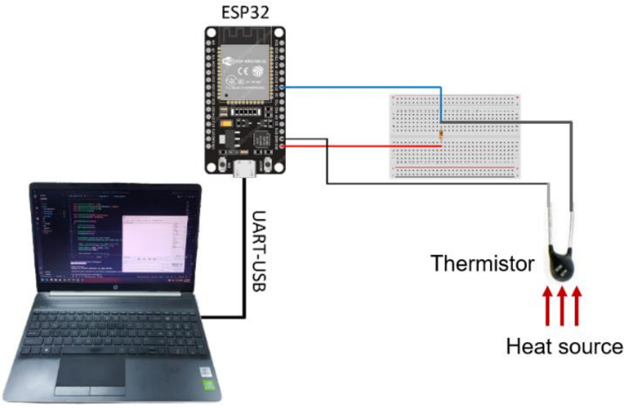
Table 1. Simulation temperature and specifications of the electronic components of the control PCB.

4.2 Measurement of the temperature of electronic components on the control PCB

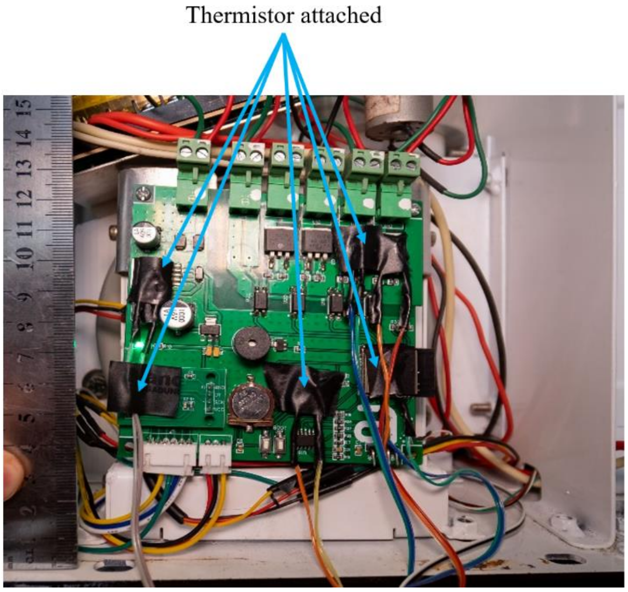
In order to verify the simulation results of heat generated from electronic components on the control PCB, the temperature of these components on the control PCB was measured by using thermal sensor (NTC MF52 thermistor).

Figure 8 (a). shows the diagram for measuring temperature using a thermistor. The temperature measurement signal was collected by using Tera Term software. The signal is collected in every 2s. Figure 8 (b). shows the setup of temperature measurement of the some main electronic components on the control PCB using the thermistors. The NTC MF52 thermistors were attached on each electronic components by using thermal paste (Arctic MX-4 thermal compound) and the electrical tape. The attachment of thermistors on the electronic components is conducted carefully so that the contact between the thermistors and the components are tight and durable during the heat measurement process.

In this work, the temperature measurement was conducted for the electronic components which the temperture is higher than 313 K (or over 40 °C, i.e. ESP32, DS3231, IRF540N, LM2576 components as shown in Table 1. The room temperature is maintained at 25 °C by using air conditioner. The disinfection machine was turned on and continuously operated for 60 minutes, and temperature of the electronic components is recorded.



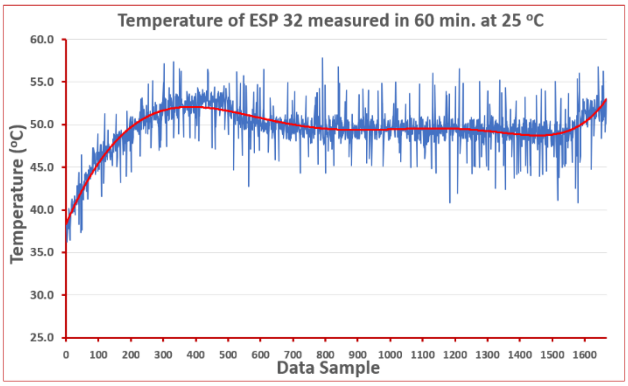
(a) Diagram for measuring temperature using thermistor



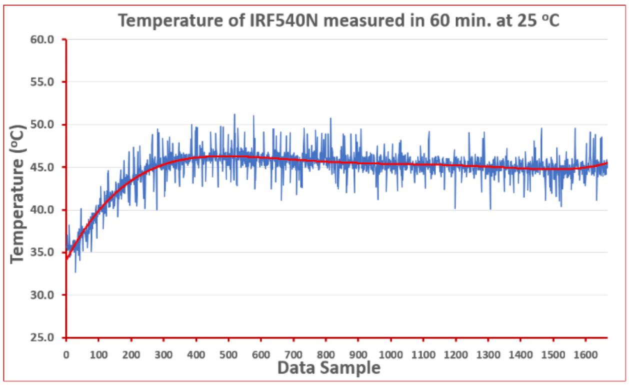
(b) Attachment of thermistors on the electronic components

Figure 8. Measuring temperature of electronic components using thermistors

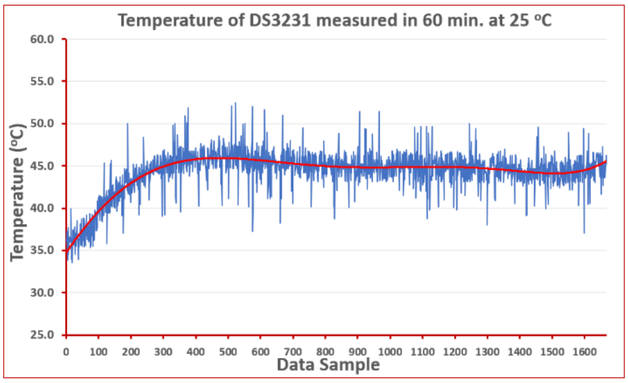
Figure 9. shows the variation of the temperature of the electronic components (i.e. the temperature of the ESP32 as in Figure 9. (a), the temperature of the IRF540N as in Figure 9. (b), the temperature of the DS3231 as in Figure 9. (c), the temperature of the LM2576 as in Figure 9. (d)) when the disinfection machine continuously operates for 60 min.



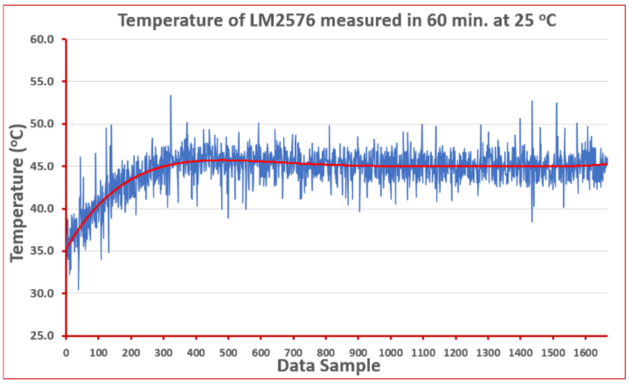
(a) Working temperature of ESP32 in 60 min.



(b) Working temperature of IRF540N in 60 min.



(c) Working temperature of DS3231 in 60 min.



(d) Working temperature of LM2576 in 60 min.

Figure 9. Variation of working temperature of the electronic components on PCB measured in 60 min.

It is found from the Figure 9 that for all the electronic components, the temperature is increased in about the first 15 min. and then it becomes stable. This implies that all the electronic components are warmed up during the first 15 min. of running, after that their temperatures reach a stable state and the average temperature of each electronic components is almost constant. It is observed from the Figure 9 that the working temperature of ESP32, IRF540N, DS3231, and LM2576 in the stable state is about 50 °C, 45 °C, 45 °C, and 44.5 °C, respectively.

Figure 10. shows the comparision of the simulation results and the measurement results of the temperature of the electronic components at the stable working state. It is found that for all the electronic components, the practical working temperature is slightly higher than the simulation temperature. This may be because following reasons: first and formost, the practical room temperature may be higher in the setting value in the simulation. In pratical experiment, the room temperature is controlled by using the air conditioner. Therefore, it could cause the non-uniform temperature in the room. In addition, their might by some difference between the setting in simulation (i.e. the materials properties of the components) and the the practical model. Last but not least, the practical working efficiency of the electronic component might be lower than the theory value as published in its datasheet. The loss of efficiency of the component is transferred in the form of heat. Therefore, the practical measured temperature of the electronic components is slightly higher than the simulation result. It is also found from the Figure 10 that the both simulation and practical measured temperature of all the electronic components are in the normal working temperature range. Therefore, the control PCB is worked well.

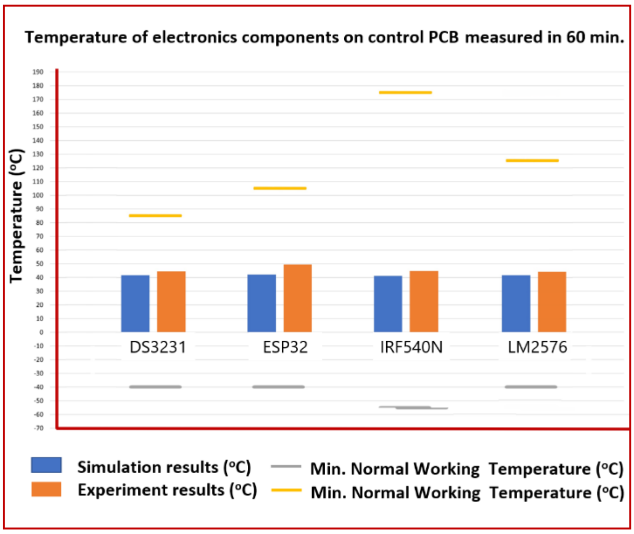


Figure 10. Comparision between simulation and measurement temperature of the electronic components on PCB

Besides developing IoT control system of the disinfection machine and study the heat generation of the control PCB, it is important to study the effects of the atomizer structure on the formation of the generated fog flow. The optimization of the atomizer structure of the disinfection machine in order to achieve powerful fog flow with fine fog particle diameter is being researched. The results will be presented in our next publications.

5 CONCLUSIONS

In this study, the authors developed a smart, high power of smart disinfection machine using IoT technology. The disinfection machine are totally remotely controlled via an application installed in an Android smart phone, and all operating parameters are real time monitored. Moreover, the operation history of the machine are fully collected and stored both on a memory card and on cloud database. In addition, the heat generation from the integrated circuits (ICs) or chip and electronic components on the control printed circuit board (PCB) is also studied by both simulation and pratical measurement. The results show that the simulation results of temperature of the electronic component is slightly lower than the practical measurement value. The highest temperature occurs at the ESP32 which is the main control ICs on the control PCB. The temperature of ESP 32 during stable operation is around 50 °C which is in the normal working temperature. It is also found that, all the temperature of all electronic components are in the normal working range. Therefore, the disinfection machine developed in this study can work well.

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REFERENCES

1. [Colakovic 2018] Colakovic A, Hadzialic M (2018) Internet of things (IoT): a review of enabling technologies, challenges and open research issues. Comput Netw 144:17–39
2. [Zikria 2019] Y.B. Zikria, S.W. Kim, O. Hahm, M.K. Afzal, M.Y. Aalsalem, Internet of Things (IoT) Operating Systems Management: Opportunities, Challenges, and Solution, Sensors. 19 (2019). https://doi.org/10.3390/s19081793.
3. [Abolghasem 2023] Abolghasem Sadeghi-Niaraki, Internet of Thing (IoT) review of review: Bibliometric overview since its foundation, Future Generation Computer Systems, Volume 143, 2023, Pages 361-377.
4. [Niti 2019] Niti Witthayawiroj and Pongpon Nilaphruek, The Development of Smart Home System for Control and Monitoring Energy Consumption using WebSocket Protocol, IOP Conf. Ser.: Mater. Sci. Eng. 185 012019.
5. [Erfani 2017] S. Erfani, M. Ahmadi and L. Chen, "The Internet of Things for smart homes: An example," Proceeding of 8th Annual Industrial Automation and Electromechanical Engineering Conference (IEMECON), pp. 153-157, doi: 10.1109/IEMECON.2017.8079580.
6. [Majhi 2021] Majhi, A.K.; Dash, S.; Barik, C.K. Arduino based smart home automation system. Accent. Trans. Inf. Secur. 2021, 6, 7–12.
7. [Babiuch 2021] M. Babiuch and J. Postulka, "Smart Home Monitoring System Using ESP32 Microcontrollers," Internet of Things, Aug. 2021, doi: 10.5772/intechopen.94589.
8. [Santama 2013] I. Santana, M. Ferre, E. Izaguirre, R. Aracil and L. Hernandez, "Remote Laboratories for Education and Research Purposes in Automatic Control Systems," in IEEE Transactions on Industrial Informatics, vol. 9, no. 1, pp. 547-556, Feb. 2013, doi: 10.1109/TII.2011.2182518.
9. [Kaluz 2014] M. Kaluz, Ľ. Cirka, ˇ R. Valo, M. Fikar, ArPi Lab: a low-cost remote laboratory for control education, IFAC Proc. Vol. 47 (2014) 9057–9062, doi:10.3182/20140824-6-ZA-1003.00963.
10. [Azad 2021] Azad, A. (2021) Design and Development of Remote Laboratories with Internet of Things Setting. Advances in Internet of Things, 11, 95-112. doi: 10.4236/ait.2021.113007.
11. [Shah 2019] Shah Nazir, Yasir Ali, Naeem Ullah, Iván García-Magariño, "Internet of Things for Healthcare Using Effects of Mobile Computing: A Systematic Literature Review", Wireless Communications and Mobile Computing, vol. 2019, Article ID 5931315, 20 pages, 2019. https://doi.org/10.1155/2019/5931315
12. [Jorge 2021] Jorge Calvillo-Arbizu, Isabel Román-Martínez, Javier Reina-Tosina, Internet of things in health: Requirements, issues, and gaps, Computer Methods and Programs in Biomedicine,Volume 208, 2021, https://doi.org/10.1016/j.cmpb.2021.106231
13. [Mostafa 2021] Mostafa Haghi Kashani, Mona Madanipour, Mohammad Nikravan, Parvaneh Asghari, Ebrahim Mahdipour, A systematic review of IoT in healthcare: Applications, techniques, and trends, Journal of Network and Computer Applications,Volume 192, 2021, https://doi.org/10.1016/j.jnca.2021.103164
14. [Caputo 2016] Caputo, A., Marzi, G., & Pellegrini, M. M. (2016). The internet of things in manufacturing innovation processes: development and application of a conceptual framework. Business Process Management Journal, 22(2), 383-402.
15. [Mohsen 2023] Mohsen Soori, Behrooz Arezoo, Roza Dastres, Internet of things for smart factories in industry 4.0, a review, Internet of Things and Cyber-Physical Systems, Volume 3, 2023, Pages 192-204.
16. [Kim 2020] Kim, WS., Lee, WS. & Kim, YJ. A Review of the Applications of the Internet of Things (IoT) for Agricultural Automation. J. Biosyst. Eng. 45, 385–400 (2020). https://doi.org/10.1007/s42853-020-00078-3.
17. [Mustafa 2017] Mustafa Alper Akkaş, Radosveta Sokullu, An IoT-based greenhouse monitoring system with Micaz motes, Procedia Computer Science, Volume 113, 2017, Pages 603-608, https://doi.org/10.1016/j.procs.2017.08.300.
18. [Bingol 2014] Bingol, O.; Tasdelen, K.; Keskin, Z.; Kocaturk, Y.E. Web-based Smart Home Automation: PLC- controlled Implementation. Acta Polytech. Hung. 2014, 11, 51–63.
19. [Cheng 2020] Cheng, Y.H.; Chao, P.J.; Liang, H.Y.; Kuo, C.N. Smart home environment management using programmable logic controller. Eng. Lett. 2020, 28, 1174–1181.
20. [Sarangapani 2021] Sarangapani, E.; Narmadhai, N.; Santhosh, N. Industry 4.0 technologies incorporated with Delta PLC based Smart Home Automation for Rural Development. IOP Conf. Ser. Mater. Sci. Eng. 2021, 1084, 012112.
21. [Sharkawy 2022] Sharkawy, A.-N.; Hasanin, M.; Sharf, M.; Mohamed, M.; Elsheikh, A. Development of Smart Home Applications Based on Arduino and Android Platforms: An Experimental Work. Automation 2022, 3, 579–595. https://doi.org/10.3390/
22. [Singh 2021] Singh, S.; Patra, A.; Shrivastav, T. Home Automation using Arduino With Bluetooth Module. Int. J. Innov. Res. Electr. Electron. Instrum. Control Eng. 2021, 9, 318–320.
23. [Allafi 2017] Allafi I and Iqbal T. Design and implementation of a low cost web server using ESP32 for real-time photovoltaic system monitoring. 2017 IEEE Electrical Power and Energy Conference, EPEC 2017. DOI: 10.1109/EPEC.2017.8286184.
24. [Abdullah 2018] Abdullah AH, Sudin S, Ajit MIM, et al. Development of ESP32-based Wi-Fi Electronic Nose System for Monitoring LPG Leakage at Gas Cylinder Refurbish Plant. nternational Conference on Computational Approach in Smart Systems Design and Applications, ICASSDA 2018. DOI: 10.1109/ICASSDA.2018.8477594.
25. [Joseph 2019] Joseph S, Francis N, John A, Farha B, Baby A, editors. Intravenous drip monitoring system for smart hospital using IoT. 2019 2nd International Conference on

Intelligent Computing, Instrumentation and Control Technologies (ICICICT); 2019: IEEE.

26. [Nursuwars 2019] Nursuwars FMS, Rahmatulloh A. RFID for nurse activity monitoring in the hospital's nurse call system with Internet of Thing (IoT) concept. IOP Conf Ser: Mater Sci Eng. 2019;550(1):012025. doi:10.1088/1757-899x/550/1/012025.

27. [Narendra 2019] K. Narendra Swaroop, Kavitha Chandu, Ramesh Gorrepotu, Subimal Deb, A health monitoring system for vital signs using IoT, Internet of Things, Volume 5, 2019, Pages 116-129, https://doi.org/10.1016/j.iot.2019.01.004.

28. [Woon-Sung 2013] Woon-Sung Baek, Dong-Min Kim, F. Bashir and Jae-Young Pyun, "Real life applicable fall detection system based on wireless body area network," 2013 IEEE 10th Consumer Communications and Networking Conference (CCNC), Las Vegas, NV, 2013, pp. 62-67, doi: 10.1109/CCNC.2013.6488426.

29. [Saadeh 2019] W. Saadeh, S. A. Butt, and M. A. B. Altaf, "A patient-specific single sensor IoT-based wearable fall prediction and detection system," IEEE transactions on neural systems and rehabilitation engineering, 2019, doi: 10.1109/TNSRE.2019.2911602.

30. [Chandra 2019] I. Chandra, N. Sivakumar, C. B. Gokulnath, and P. Parthasarathy, "IoT based fall detection and ambient assisted system for the elderly," Cluster Computing, vol. 22, pp. 2517-2525, 2019, doi: 10.1007/s10586-018-2329-2.

31. [Pedram 2006] Pedram, M., Nazarian, S., Thermal modeling, analysis, and management in VLSI circuits: Principles and methods, Proceedings of the IEEE, Volume 94, Issue 8, August 2006, Pages 1487-1501.

32. [Zulfiqar Khattak 2019] Zulfiqar Khattak, Hafiz Muhammad Ali, Air cooled heat sink geometries subjected to forced flow: A critical review, International Journal of Heat and Mass Transfer, Volume 130, 2019, Pages 141-161,

33. [Mallik 1995] A.K. Mallik, G.P. Peterson, Steady-state investigation of vapor deposited microheat pipe arrays, J. Electron. Packag. 117 (1995) 75–81.

34. [Lakshminarayanan 2014] V. Lakshminarayanan, N. Sriraam, The effect of temperature on the reliability of electronic components, in: 2014 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), 2014, pp. 1–6.